Bibliography on Aircraft Hazard Studies

(enclosure to answer 4.d)

1. Authors: L'huby, Y., Chauvel, -D.
Title: Design study of a French nuclear plant under aircraft impact according to German guidelines.
Publication: 11th International Conference on Structural Mechanics in Reactor Technology. Tokyo (Japan), v. J, pp. 39-44, 18-23 Aug 1991.
Abstract: Subject of the paper is the presentation of an aircraft protection for the reactor building and the electrical building of the French nuclear plant P'4 or N4 against the aircraft impact load conditions according to German guidelines. Furthermore, floor response spectra in the interior of the two buildings are evaluated for the induced vibrations resistant design of components. The presented solution leads to acceptable values of either necessary bending and stirrup reinforcements and of the level of equipment accelerations for the reactor building as well as for the electrical building.

2. Authors: International Atomic Energy Agency, Vienna (Austria)
Title: External man-induced events in relation to nuclear power plant design. A safety guide.
Publication: International Atomic Energy Agency, Safety Series, No. 50-SG-D5, 1982
Abstract: This Guide deals with the basic design requirements for nuclear power plants, and presents a general design approach for protection against the effects of man-induced events. Section 2 discusses the general design approach. Section 3 outlines the development of the basic information necessary for an evaluation of the adequacy of a design against the effects of aircraft crashes, fires, explosions, and the release of toxic gases or corrosive substances. Section 4 outlines the design logic for protection against external man-induced events. It indicates possible methods of ensuring overall plant safety, including protection against possible secondary effects. Included for each event are: a methodology for calculating the design input parameters from the data generated in the siting study, system protection considerations from the effects of this man-induced event, and criteria for judging the adequacy of the protection provided. Specific design guidance related to acts of sabotage is not provided in this Guide. It should be recognized, however, that for certain situations such acts can be important to safety and could constitute the controlling postulated initiating event for design. The list of events covered is not necessarily complete. However, important events on which enough work has already been done in various Member States to enable their effects to be converted into generally accepted design parameters are included. In addition, other man-induced events such as dam ruptures, ship collisions, construction accidents and the like are identified but no general guidelines for design can be specified for these at present. These events need to be considered on an ad hoc basis, in order to arrive at design input parameters for them.

3. Authors: Rosa,-L.P.; Oliveria,-L.F.; Barros,-E.B.; Fleming,-P.V
Title: Cost effectiveness of risk-reduction measures for nuclear plants.
Publication: International conference on nuclear power plant aging, availability factor and reliability analysis; San Diego, CA, 7-12 July, 1985, pp. 247-252
Abstract: In this paper the systemic or global approach to cost-effectiveness analysis of risk-reduction measures is reviewed, and its advantages and limitations are discussed. The method is applied to the problem of the cost-effectiveness of increasing the Angra 3 NPP containment wall thickness from the present 60 cm to 180 cm thick in order to prevent damage to the reactor core in case of a direct commercial aircraft crash on it. It is concluded that this measure is not cost-effective if the global approach is considered.

4. Authors: Mischke,-J.; Hilpert,-H.J.
Title: Vibration isolation of a building against earthquake, airplane crash and blast.
Publication: Nuclear Engineering and Design, Netherlands, April 1986, v. 92(2), pp 153-167
Abstract: The influence of three different support concepts on the vibration responses of a building to the load cases earthquake, airplane crash and blast is numerically investigated. Compared are the three concepts: the standard version of a double shell structure with a combined base for inner and outer building without isolation system; the same building with isolation system between foundation slab and soil, as vibration isolation known so far; and as a third concept a double shell structure with completely separated inner and outer building, where the isolation system is placed between the two parts of the building. The results show that, compared to the standard concept, the third concept leads to a nearly complete isolation of shock-induced vibrations, and to a reduction of the vibrations caused by an earthquake, comparable to the reduction in the isolation concept known so far.

5. Authors: Chadmail,-J.F.
Title: Equivalent loading due to airplane impact taking into account the non-linearities of impacted reinforced concrete buildings.
Publication: Nuclear Engineering and Design, Netherlands, February 1985, v. 85(1), pp 47-57
Abstract: The object of the paper is to present a numerical method of determining the dynamic response at characteristic points of the building taking into account the non-linear behavior of locally impacted cracked damaged concrete. The method is based on the determination of a verified load function (VLF) which, applied to a linear elastic model of the structure, leads to the same response of the building (far from the impact point) as that due to the RLF impact force applied to a more realistic non-linear model of the reinforced concrete building. The practical advantage of using this procedure is that it avoids long and costly non-linear time integration of a full structural model. In order to obtain the VLF one only performs non-linear explicit calculations locally which include the main physical phenomenon occurring in an impacted reinforced concrete structure.

6. Authors: Renn,-W.; Scharpf,-F.; Schittke,-H.J.; Schwarz,-R.
Title: Numerical simulation of fuel spillage following an aircraft impact onto a nuclear power plant.
Publication: Transactions of the 8th international conference on structural mechanics in reactor technology, vol. B, computer methods for structural analysis, pp. 117-122, 1985
Abstract: The possible consequences of fuel discharging from the tanks of an impacting aircraft is of interest in security analysis concerning nuclear power plant buildings. In the problem presented here the propagation of approximately 4.4 cubic meters of fuel from the fuselage tank of a Phantom F4 through the damaged roof structure of a sensitive building is simulated by means of the fluid-dynamics code DYSMAS/E. The results of this investigation show that under worst-case conditions about 17% of the total mass of fuel may flow through the cracked structure, whereas in most cases the actual inflow will be much less.

7. Authors: Hall,-S.F.; Phillips,-D.W.; Peckover,-R.S.
Title: An overview of external hazard assessment.
Publication: Nuclear Energy, UK, v.24(4), pp. 211-227, August 1985.
Abstract: Four external hazards are discussed: earthquakes, aircraft crashes, fires, and gas cloud explosions. Historically the assessments have been hampered by different factors. For earthquakes, the difficulty lies in estimating the probability of a damaging earthquake in a seismically 'passive' region of the earth's surface. For aircraft crashes, the main uncertainty lies in assessing the effect on the functioning of the plant of an aircraft crash. For fires and gas cloud explosions, both the physics and the assessment methodology were not well developed; this has to a large extent been rectified and realistic risk assessments are feasible. The assessment of external hazards fits easily into the framework of probabilistic methods. Its use may result in a significant feedback from PRA to the design process; such a coupling, in a major way, would be a new departure.

8. Authors: Buchhardt,-F.; Magiera,-G.; Matthees,-W.; Weber,-M.
Title: Sensitivity of nuclear power plant structural response to aircraft impact.
Publication: Proceedings of the Conference on Structural Analysis and Design of Nuclear Power Plants, V.3, pp. 111-114, 1984
Abstract: In this paper a sensitivity study for aircraft impact is performed concerning the excitation of internal components, with particular regard to nonlinear structural material behavior in the impact area. The nonlinear material values are varied within the bandwidth of suitable material strength, depending on local stiffness pre-calculations. The analyses are then performed on a globally discretized three-dimensional finite element model of a nuclear power plant, using a relatively fine mesh. For specified nodal points results are evaluated by comparing their response spectra.

9. Authors: Henkel,-F.O.; Woelfel,-H.
Title: Building concepts against airplane crash.
Publication: Nuclear Engineering and Design - Netherlands, v. 79(3) pp. 397-409, June 1984
Abstract: In Germany safety related buildings of nuclear facilities as well as their equipment are to be designed against airplane crash. While the safety of the structure itself can always be guaranteed by structural means, the induced vibrations may cause severe problems for the equipment. Considerable effort was expended in recent years to comprehend the load case airplane crash in a more exact manner and to evaluate reasonable floor response spectra. Besides this analytical effort, investigations are cited to minimize the induced vibrations by new structural concepts. The present paper gives a survey concerning the development of structural concepts, culminating in the double shell structures that are state of the art today. Then the idea of spring supports, as it is known for the seismic foundation of buildings, is further developed to a new spring concept which reduces the induced vibrations in an optimum way in the load case airplane crash and which additionally isolates earthquake vibrations.

10. Authors: Seehars,-H.D.
Title: Release of Pu-containing materials during a kerosene fire.
Publications: Journal of Aerosol Science - UK, v.14(3), pp. 446-451, 1983
Abstract: These investigations were part of a research program to simulate the consequences of a crash of a military airplane on a fuel element fabrication plant. Such an accident gives rise to the release of respirable fine dust of Pu-compounds by three mechanisms: (1) Spontaneous release connected with the ignition, explosion and deflagration a short time after the impact of the plane. (2) Release during the k erosene fire by strong turbulence and thermal lift above the scene of conflagration. (3) Resuspension of settled particles by the wind and turbulence after

the end of the fire. The investigations discussed here are exclusively related to mechanism 2.

11. Authors: Hilpert,-H.J.
Title: Dynamic analysis and response spectra for the main process building of a reprocessing plant.
Publication: Nuclear Engineering and Design, v. 108(3), pp. 437-445, Jul-Aug 1988
Abstract: This paper deals with the determination of the floor response spectra for the main process building of the planned reprocessing plant due to the special loading conditions of earthquake, airplane crash and blast. With these spectra the stress and strain of the components and their bearing forces which react on the building can be calculated. Some special problems depending on the length of the building are not yet answered and will be discussed later. (orig.)

12. Authors: Byrne,-J.P. (AEA Reactor Services, Risley (United Kingdom))
Title: Aircraft crash studies in the UK and Europe.
Publication: International conference on nuclear power plant safety standards: towards international harmonization, pp. 187-194. 1993
Abstract: Different methods are used in European countries to assess the frequency and consequences of aircraft crashes on nuclear installations. Regulatory requirements often need to be complied with for new NPP sites, but for older sites 'backfitting' has been applied. Regulatory requirements and the methods used for frequency and consequence analysis are summarized, and the case for standardization in these and other areas is assessed. (author).

13. Authors: Ravindra,-M.K.; Banon,-H.
Title: Methods for external event screening quantification: Risk Methods Integration and Evaluation Program (RMIEP) methods development.
Publication: U.S. Nuclear Regulatory Commission, Washington, DC NUREG/CR-4839; SAND-87-7156, 1992
Abstract: In this report, the scoping quantification procedures for external events in probabilistic risk assessments of nuclear power plants are described. External event analysis in a PRA has three important goals; (1) the analysis should be complete in that all events are considered; (2) by following some selected screening criteria, the more significant events are identified for detailed analysis; (3) the selected events are analyzed in depth by taking into account the unique features of the events: hazard, fragility of structures and equipment, external-event initiated accident sequences, etc. Based on the above goals, external event analysis may be considered as a three-stage process: Stage I: Identification and Initial Screening of External Events; Stage II: Bounding Analysis; Stage III: Detailed Risk Analysis. In the present report, first, a review of published PRAs is given to focus on the significance and treatment of external events in full-scope PRAs. Except for seismic, flooding, fire, and extreme wind events, the contributions of other external events to plant risk have been found to be negligible. Second, scoping methods for external events not covered in detail in the NRC's PRA Procedures Guide are provided. For this purpose, bounding analyses for transportation accidents, extreme winds and tornadoes, aircraft impacts, turbine missiles, and chemical release are described.

14. Authors: Birbraer,-A.N.; Roleder,-A.J.; Arhipov,-S.B.
Title: Probabilistic assessment of NPP safety under aircraft impact
Publication: International Atomic Energy Agency, Vienna (Austria) Coordinated research programme on safety of RBMK type NPPs in relation to external events. V. 1. Working materia,l p. 13 p, 1999
Abstract: Methodology of probabilistic assessment of NPP safety under aircraft impact is described below. The assessment is made taking into account not only the fact of aircraft fall onto the NPP building, but another casual parameters too, namely an aircraft class, velocity and mass, as well as point and angle of its impact with the building structure. This analysis can permit to justify the decrease of the required structure strength and dynamic loads on the NPP equipment. It can also be especially useful when assessing the safety of existing NPP. (author)

15. Authors: Birbraer,-A.N.; Roleder,-A.J.; Shulman,-G.S.
Title: Probabilistic approach to requalification of existing NPPs under aircraft crash loading
Publication: International Atomic Energy Agency, Vienna (Austria) Upgrading of existing NPPs with 440 and 1000 MW WWER type pressurized water reactors for severe external loading conditions. Proceedings. Working material. V. 1, 2, pp. 325-334, 1993
Abstract: A probabilistic approach to the analysis of NPP safety under aircraft impact is discussed. It may be used both for requalification of existing NPPs and in the process of NPP design. NPP is considered as a system of components: structures, pipes, different kinds of equipment, soil, foundation. The exceeding of the limit probability of the radioactive products release out of containment (i.e. of the NPP safety requirements non-fulfilment) is taken as a system failure criterion. An example of an event tree representing the consequence of events causing the failure is given. Described are the methods of estimate of elementary events probabilities through which a composite probability of the failure is evaluated.

16. Authors: Bonetti,-P., Brusa,-L.; Contri,-P.
Title: Dual concrete containment design with optimal resistance to aircraft impact and earthquake. Design sensitivity supported by mathematical models.
Publication: 13th International conference on structural mechanics in reactor technology. v. 4, pp. 237-242, 13-18 Aug 1995.
Abstract: As per current practice in most of the European countries, protection against aircraft crash is required. Notwithstanding some national regulatory differences, this protection is in general very expensive. Therefore an optimization design process could be very advantageous. In fact the secondary containment design has to satisfy both impact and seismic requirements, as in many cases earthquake resistance is a lower limit for the thickness. The final optimal size is a compromise between the two requirements and it guarantees at the same time both the cheapest global configuration and the minimum impact on the existing design. The results of a large numerical analysis programme is presented, based on the most recent experimental data and computer codes.

17. Authors: USDOE, Assistant Secretary for Environment, Safety, and Health,
Title: Accident analysis for aircraft crash into hazardous facilities.
Publication: DOE standard 3014–96, 1996
Abstract: This standard provides the user with sufficient information to evaluate and assess the significance of aircraft crash risk on facility safety without expending excessive effort where it is not required. It establishes an approach for performing a conservative analysis of the risk posed by a release of hazardous radioactive or chemical material resulting from an aircraft crash into a facility containing significant quantities of such material. This can establish whether a facility has a significant potential for an aircraft impact and whether this has the potential for producing

significant offsite or onsite consequences. General implementation guidance, screening and evaluation guidelines, and methodologies for the evaluations are included.

18. Authors: Kimura,-C.Y.; Glaser,-R.E.; Mensing,-R.W.; Lin,-T.; Haley,-T.A.; Barto,-A.B.; Stutzke,-M.A.
Title: Data development technical support document for the aircraft crash risk analysis methodology (ACRAM) standard.
Publication: Lawrence Livermore National Laboratory, UCRL-ID--124837, 1996
Abstract: The Aircraft Crash Risk Analysis Methodology (ACRAM) Panel has been formed by the US Department of Energy Office of Defense Programs (DOE/DP) for the purpose of developing a standard methodology for determining the risk from aircraft crashes onto DOE ground facilities. In order to accomplish this goal, the ACRAM panel has been divided into four teams, the data development team, the model evaluation team, the structural analysis team, and the consequence team. Each team, consisting of at least one member of the ACRAM plus additional DOE and DOE contractor personnel, specializes in the development of the methodology assigned to that team. This report documents the work performed by the data development team and provides the technical basis for the data used by the ACRAM Standard for determining the aircraft crash frequency. This report should be used to provide the generic data needed to calculate the aircraft crash frequency into the facility under consideration as part of the process for determining the aircraft crash risk to ground facilities as given by the DOE Standard Aircraft Crash Risk Assessment Methodology (ACRAM). Some broad guidance is presented on how to obtain the needed site-specific and facility specific data but this data is not provided by this document.

19. Authors:
Title: Alto Lazio: a new BWR station for Italy.
Publication: Nuclear-Engineering-International (Dec 1983). v. 28(349) p. 37-40.
Abstract: Commissioning of the first 981 We reactor of the two-unit Alto Lazio station, now under construction at Montalto di Castro in Italy, is due in June 1987. Project status and main design features including special measures for protection against serious external events (e.g. air crash and earthquake), post Three Mile Island control room modifications, and compliance with the latest electrical equipment qualification requirements are described.

20. Authors: Kobayashi,-Toshio (Kajima Construction Co. Ltd., Chofu, Tokyo (Japan). Inst. of Construction Technology)
Title: Probability analysis of an aircraft crash to a nuclear power plant.
Publication: Nuclear-Engineering-and-Design. (Dec 1988). v. 110(2) p. 207-211.
Abstract: Formulae to evaluate the probability of an aircraft crash onto a nuclear power plant are discussed. Four formulae introduced in the references are reviewed. They are used to evaluate the probability of an aircraft crash for four flying patterns, namely, 'Landing on and/or taking off the airport', 'Near airport', 'Straight flight path' and 'Racetrack pattern flight', respectively. The formulae to evaluate the crash probability for a 'Free flight zone' is newly proposed by the author. All formulae are accompanied by numerical examples adequately idealized to flying conditions. (orig.).

21. Authors: Eibl,-J. (Institut fuer Massivbau und Baustofftechnologie, Universitaet Karlsruhe, Karlsruhe (Germany)); Kobler,-G. (Institut fuer Massivbau und Baustofftechnologie, Universitaet Karlsruhe, Karlsruhe (Germany))
Title: Impact research for containment design.
Publication: Nuclear-Engineering-and-Design. (30 Sep 1994). v. 150(2-3). p. 409-415.

Abstract: Engaged for many years in research work concerning the safety and integrity of nuclear containments, the first author has performed numerous theoretical and experimental investigations at this institute. Airplane crashes on nuclear power plants, as well as containment attacks by detonation and missiles generated by bursting vessels have been studied with respect to practical design. Also, a series of fundamental researches has been done to evaluate constitutive laws for shockwaves in concrete and constitutive relations for concrete with regard to strain rate effects. Further investigations have focused on friction phenomena for projectiles impinging on concrete.

Question 5: According to the report, Germany requires essentially all nuclear containment structures to withstand the crash of certain types of military and commercial aircraft, and the International Atomic Energy Agency has also recommended a systematic approach to the problem of aircraft hazards.

a) Does the NRC require its licensees to follow the IAEA system? If not, why not?

b) Given that the NRC was aware that other nations required nuclear containment structures to be able to withstand the crash of certain types of military and commercial aircraft as long as 20 years ago, why didn't it require U.S. nuclear facilities to ensure they had the same capabilities?

Answer:

a) No. The NRC determines the acceptability of a reactor site with respect to aircraft hazards on the basis of a risk assessment. The principal criterion of acceptance is the likelihood of exceeding 10 CFR Part 100 dose guidelines is acceptably low. As indicated in our October 16, 2001 letter, this involves consideration of the likelihood of the initiating event, as well as the probability of plant damage and release. Typically, if the initiating event has a sufficiently low probability of occurrence, the risk associated with an event such as an aircraft crash is considered to be insignificant. If not, then an assessment is made of the plant in terms of the likelihood of sustaining damage sufficient to cause a release in excess of 10 CFR Part 100 dose guidelines.

b) The major reason that European countries such as Switzerland and Germany have required deterministic design features for protection from aircraft impacts is the significantly higher traffic densities of both military and commercial aircraft and crash rates. For example, the Argonne report indicates that in some parts of Europe, exposure to potential aircraft crashes is higher than in the U.S. by as much as a factor of 25. This led to a probabilistically-based decision to provide structural protection against aircraft impacts.

The likelihood of an airplane accidentally crashing onto a reactor site in the U.S. is typically much lower than in Europe. Therefore, deterministic protection requirements are imposed only when the likelihood of a crash is found to be unacceptably high. Hence, although the technical basis is similar in the U.S. and Europe, the specific requirements differ due to dissimilar exposures to aircraft hazards.

Question 6: The report states that while the control rods can be dropped quickly without electrical power to halt a core meltdown, this will only succeed in bringing the plant from full power down to hot standby conditions. Bringing the plant down to cold shutdown conditions would require the injection of boron, which does require electrical power.

a) How long can a reactor stay in hot standby mode before it becomes a problem, in the event that electrical power is shut down by a terrorist attack or accident?

b) Please describe the consequences of a prolonged electrical power shut down on the reactor. How long would it take before a core meltdown was initiated?

Answer:

Hot shutdown is generally the mode that plants are designed to achieve following a design bases event (such as a large earthquake or a loss of coolant accident.) While pressurized water reactors may require addition of boron to achieve cold shutdown (to maintain the reactor with an adequate degree of subcriticality), boiling water reactors do not require the addition of boron to achieve this mode. More pertinent is the need to remove decay heat to the extent that the water in the reactor is cold enough to be considered in "cold" shutdown. This heat removal process does require use of heat exchangers and forced circulation, which in turn requires electrical power.

a) If offsite power is lost, but the emergency diesel generators are unaffected, the plant can stay at hot shutdown indefinitely. If a station blackout exists (i.e., all ac power is lost), the time to core damage depends on equipment capability and capacity such as station battery capacity, environmental effects (for continued equipment operation), water inventory in emergency tanks, reactor coolant pump seal leakage (for PWRs), ability to depressurize and cool the reactor core using diesel-driven fire pumps (BWRs), and suppression pool temperature (for BWRs). According to 10 CFR 50.63, each light water cooled reactor must be able to withstand a station blackout for a specified period. The minimum coping time is four hours (as demonstrated by a conservative analysis), with a number of plants being able to withstand eight or more hours of ac power loss and other plants having alternate means of supplying ac power (such as gas turbines). For PWRs, reactor decay heat can be removed by use of a steam-driven or dedicated diesel-driven train of the auxiliary feedwater system. Decay heat would be rejected to the environment by the atmospheric dump valves. BWRs have two functionally different classes: those that use an isolation condenser cooling system for decay heat removal and do not have a makeup capability independent of ac power; and those with a reactor core isolation cooling system and either a steam-driven high pressure coolant injection system or high pressure core spray system with a dedicated diesel. As long as the operators retain the capability to replenish water in tanks, and as long as the station batteries have sufficient charge for control and instrument power, both BWRs and PWRs can operate for extended periods at hot shutdown.

b) For most plants if all ac power is lost, the time to core damage depends on the capabilities and capacities of support systems, such as the quantity and availability of water required for decay heat rejection, the capacity of dc power supplies, and compressed air reserves. Often the limiting equipment is the station batteries. The batteries provide power for instrumentation needed by the operators and control power

for valves and other equipment needed to remove decay heat from the reactor (e.g., steam-driven auxiliary feedwater pumps or high pressure coolant injection pumps, which are also steam driven). Operators are trained to extend the capability of the batteries by shedding unnecessary electrical loads in the event of a station blackout. If the batteries fail, the decay heat removal systems generally will fail too, due to loss of control of valves controlling the steam to the pump turbines, or other causes. A limited number of plants may have some ability to remove decay heat by manual operation and control of steam-driven turbine pumps. Such evolutions include operator responses and it would be problematic to assign high likelihood of successful operation for an extended period (i.e., much beyond a few hours.) An additional concern is loss of inventory to the reactor coolant system (perhaps due to reactor coolant pump seal leakage.) If too much inventory is lost, natural circulation will be lost for PWRs or BWRs with isolation condensers. The time to core damage is also a function of the time after reactor scram that all electrical power (including the batteries) is lost. The shortest times to core damage would occur if the loss of all electrical power (i.e., offsite power, onsite emergency power from the diesel generators, and dc power from the station batteries) were to occur at the time of reactor scram. Depending on the plant design, it would take about an hour for the core to become uncovered. Core damage would probably begin to occur about an hour after the core began to be uncovered. Operator and emergency actions would mitigate the efforts of this postulated condition.

Question 7: The report states that the "condenser and condenser cooling water system, parts of the feedwater system and the steam lines, as well as the water intakes and ultimate heat sink(s) are not protected inside hardened structures; they are thus vulnerable to direct impact. Moreover, though the residual heat removal system itself is fully contained in the hardened containment and auxiliary buildings, its intermediate heat removal circuit and ultimate heat sink are not protected in that way."

a) What would happen if any of these auxiliary structures were destroyed by an airplane crash, truck bomb, or other means of attack or accident?

b) Will the NRC be requiring these auxiliary structures to be better protected in the future in order to prevent releases of radioactive materials? If not, why not?

Answer:

Important support systems for safety grade systems such as the residual heat removal system are not necessarily inside containment, which is the most hardened structure in the plant. Such systems are protected against missiles, tornadoes, hurricanes, fires, and seismic events. Similarly the ultimate heat sink must have the capability to withstand significant events such as hurricanes or a design bases earthquake. It is incorrect to state that such systems are not protected in any way. However, they are not designed to withstand the direct impact of a large aircraft. Plants are designed to withstand the design basis vehicle threat.

a) There are several auxiliary buildings (large and small) at nuclear power plant sites. The destruction of many, if not most, of these would not directly lead to core damage, as the functions provided by the equipment in the structures is not necessary to safely shut down the reactor. However, there are a few buildings at every site whose partial or total destruction from an attack could lead to core damage if key support systems were lost for an extended period of time without available compensatory measures. Operator and emergency actions would mitigate the effects of these postulated conditions.

b) The Commission is currently considering what actions are warranted as a result of the September 11 attack.

Question 8: The report states that "A crash of an aircraft on a switchyard would very likely eliminate the plant's offsite power .... Should massive electrical failure leading to total loss of power be possible (with the diesel generators failing or unable to deliver power because of short circuits or other equipment failures) it would leave the plant vulnerable to core melt."

a) Do you agree with these statements? If not, why not?

b) How long would it take after an attack or accident caused a massive electrical failure for a core melt of the reactor to occur?

Answer:

a) We agree that a large aircraft crashing into a plant's switchyard would likely cause a loss of offsite power. However, some plants are configured so that there are other units or lines that would not be affected by such a crash and could provide ac power. Even if offsite power were lost due to an aircraft crash into the plant's switchyard, we do not believe that the plant would experience a core melt. First, the emergency diesel generators are highly reliable and a crash in the switchyard would not generally damage the capability of the diesels to start, load, and carry their emergency electrical demands. In addition, per the requirements of 10 CFR 50.63, each light water cooled reactor must be able to withstand a station blackout for a specified period. The minimum coping time is four hours (as demonstrated by a conservative analysis), with a number of plants being able to withstand eight or more hours of ac power loss and other plants having alternate means of supplying ac power (such as gas turbines). These capabilities should not be affected by a plane crash into the switchyard.

b) If a station blackout were to occur, plants are designed to be able to handle a blackout lasting at least four hours, with many plants capable of longer periods before the core would be uncovered. There are a number of mitigative actions that could be taken during this time to lengthen the capability of the plant to withstand the blackout. We have asked licensees to assure they have considered such contingencies and have preplanned for them. As discussed in response to question 6, if these measures are unsuccessful, the reactor coolant will heat up and boil off, resulting in the onset of core damage several hours following loss of core cooling. Operator and emergency actions would mitigate the effects of this postulated condition.

Question 9: The report states that "additional ways in which a nuclear power plant could be seriously affected, different from a direct impact on a hardened structure, would be by impact on systems affecting long-term heat removal capability such as the turbine hall (severing the steam lines) and the water intakes. It should be kept in mind that the combined effects of impact and fire due to an aircraft crash open the possibility for numerous multiple failures;"

a) Do you agree with these statements? If not, why not?

b) How long would it take for a core melt of the reactor to occur if the long-term heat removal capabilities were destroyed? What are you doing to ensure that this will not occur?

Answer:

a) Yes, we agree. Loss of the mentioned systems would be similar to a station blackout, which also affects multiple systems.

b) The time to a core melt would vary according to the design of the plant and the equipment damaged in the attack. In many cases there would be various mitigative strategies that could be employed. For example, severing the steam lines would not prevent the motor-driven auxiliary feedwater pumps (PWRs) or the low pressure coolant injection pumps (BWRs) from functioning and providing decay heat removal. Damage to the intake structures (or more generally the ultimate heat sink) would cause a long term heat up of the coolant systems and would eventually result in effects similar to that of a station blackout once the normal emergency systems were no longer capable of providing their safety functions due to loss of ultimate heat sink cooling. At Three Mile Island it was decided not to attempt to use the decay heat removal system to bring Unit 2 to cold shutdown following its core damage accident. Instead, the auxiliary feedwater pumps and the steam generators were used to remove decay heat from the reactor coolant system.

Following the September 11th events, the NRC performed a preliminary assessment of the dependence of emergency service water on the intake structures and alternate systems that might be used for cooling in the event the intake structure is lost. Based on this assessment, the NRC believes that sufficient alternate heat removal capabilities are available to preclude core damage (this is based on the expectation that ac power will remain available in attacks on the intake structures. In addition, in response to the October 6, 2001, Safeguards Advisory, licensees are taking steps to assure that their emergency procedures and accident management guidelines include sufficient guidance to deal with the potential effects of damage to very large areas of the plant including intake structures from an aircraft impact or other threats beyond the design basis.

Question 10: According to the report, if the secondary cooling system of the plant and a total electrical power failure were to simultaneously occur at a reactor, the result would be a re-criticality of the core, even if the containment structure wasn't penetrated at all by the attack on or accident at the reactor. It concludes that in these circumstances, "the core would most probably be headed for serious damage if not total meltdown. Core meltdown, without the availability of electrical power, would probably result in containment over-pressurization and release of radioactive materials to the environment far in excess of 10 CFR 100 guidelines."

a) Do you agree with the report's conclusion that it would be possible for terrorists to cause a core melt at a nuclear reactor even without breaching the containment? If not, why not?

b) What steps are you taking to protect the electrical power supply and secondary cooling systems of the reactors, especially in light of the events of September 11?

c) Have these systems' security been tested using Operational Safeguards Response Evaluation exercises at any of the nation's facilities? If so, what were the results? If not, then how do you know such systems are not vulnerable to terrorist attack?

Answer:

The answer to this question contains sensitive information, not for public disclosure. Therefore, it has been separated from this enclosure to allow the information in it to be controlled, and not be publicly released.

Question 11: The Argonne report concludes that "based on the review of past licensing experience, it appears that fire and explosion hazards have been treated with much less care than the direct aircraft impact and the resulting structural response. Therefore, the claim that these fire/explosion effects do not represent a threat to nuclear power plant facilities has not been clearly demonstrated." Has the NRC analyzed the threat of fir/explosion effects associated with an aircraft impact since the Argonne report was published in 1982? If not, why not, and do you plan to do so now, in light of the events of September 11?

Answer:

In a later NRC report (NUREG/CR-5042, dated 1987) the effects of fires due to aircraft fuel were considered to be of secondary importance in relation to the direct physical damage caused by aircraft impact. This view was based on the indication that there was insufficient fuel aboard aircraft to do substantial damage. Although no detailed fire/explosion studies have been made, in light of the events of September 11, the NRC intends to consider this issue in the reevaluation of the security and physical protection program.